I. Overview

Hanford's B Reactor was the first plutonium-production reactor in the world. Plutonium created within this reactor fueled the first atomic explosion in the Alamogordo desert on July 16, 1945, and it formed the core of the bomb that exploded over Nagasaki on August 9, 1945. Built in less than a year, the B Reactor operated from 1944 to 1968. It has been designated a National Historic Mechanical Engineering Landmark. *Hanford Site, Washington. November 16, 1984.*

On a cold morning in December 1989, workers at the Rocky Flats Plant in Colorado loaded the last plutonium "trigger" for a nuclear warhead into a tractor trailer bound southeast to the Pantex Plant near Amarillo, Texas. No one knew then that the nuclear weapon built with this plutonium trigger would be the last one made in the United States for the foreseeable future. Until then, the production of nuclear weapons had run continuously, beginning during World War II with the startup of the first reactor to produce plutonium for the top-secret Manhattan Project. But growing concerns about safety and environmental problems had caused various parts of the weapons-producing complex to be shut down in the 1980s. These shutdowns, at first expected to be temporary, became permanent when the Soviet Union dissolved in 1991. The nuclear arms race of the Cold War came to a halt for the first time since the invention of the atomic bomb. Quietly, a new era had begun.

The Manhattan Project

The quest for nuclear explosives, driven by the fear that Hitler's Germany might invent them first, was an epic, top-secret engineering and industrial venture in the United States during World War II. The term "Manhattan Project" has become a byword for an enormous breakneck effort involving vast resources and the best scientific minds in the world. The workers on the Manhattan Project took on a nearly impossible challenge to address a grave threat to the national security.

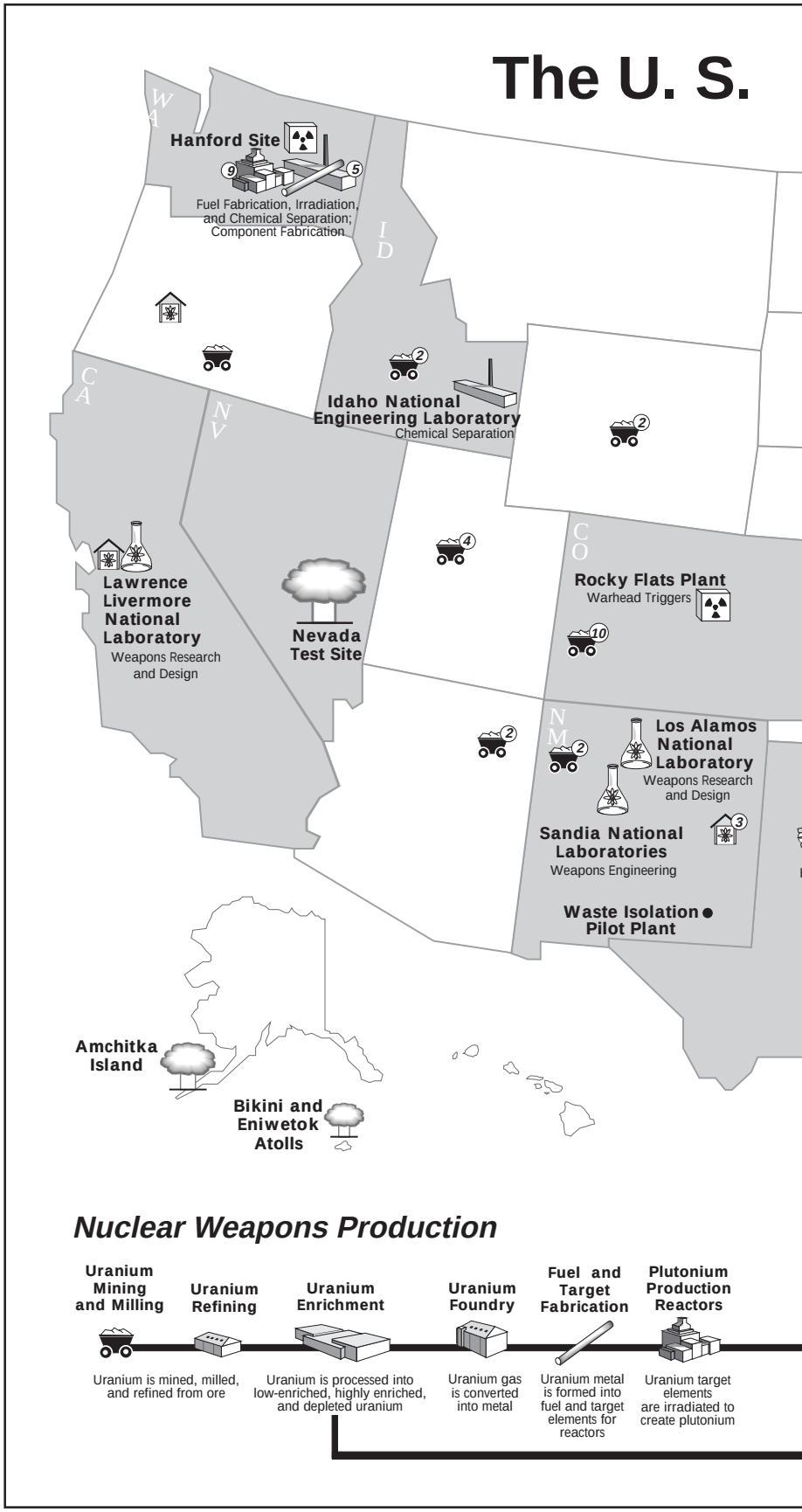
From its beginning with Enrico Fermi's graphite-pile reactor under the bleachers of Stagg Field at the University of Chicago to the fiery explosion of the first atomic bomb near Alamogordo, New Mexico, the Manhattan Project took a little less than 3 years to create a working atomic bomb. During that time, the U.S. Army Corps of Engineers managed the construction of monumental plants to enrich uranium, three production reactors to make plutonium, and two reprocessing plants to extract plutonium from the reactor fuel. In 1939, Nobel Prize-winning physicist Niels Bohr had argued that building an atomic bomb "can never be done unless you turn the United States into one huge factory." Years later, he told his colleague Edward Teller, "I told you it couldn't be done without turning the whole country into a factory. You have done just that."

The Cold War and the Nuclear Weapons Complex

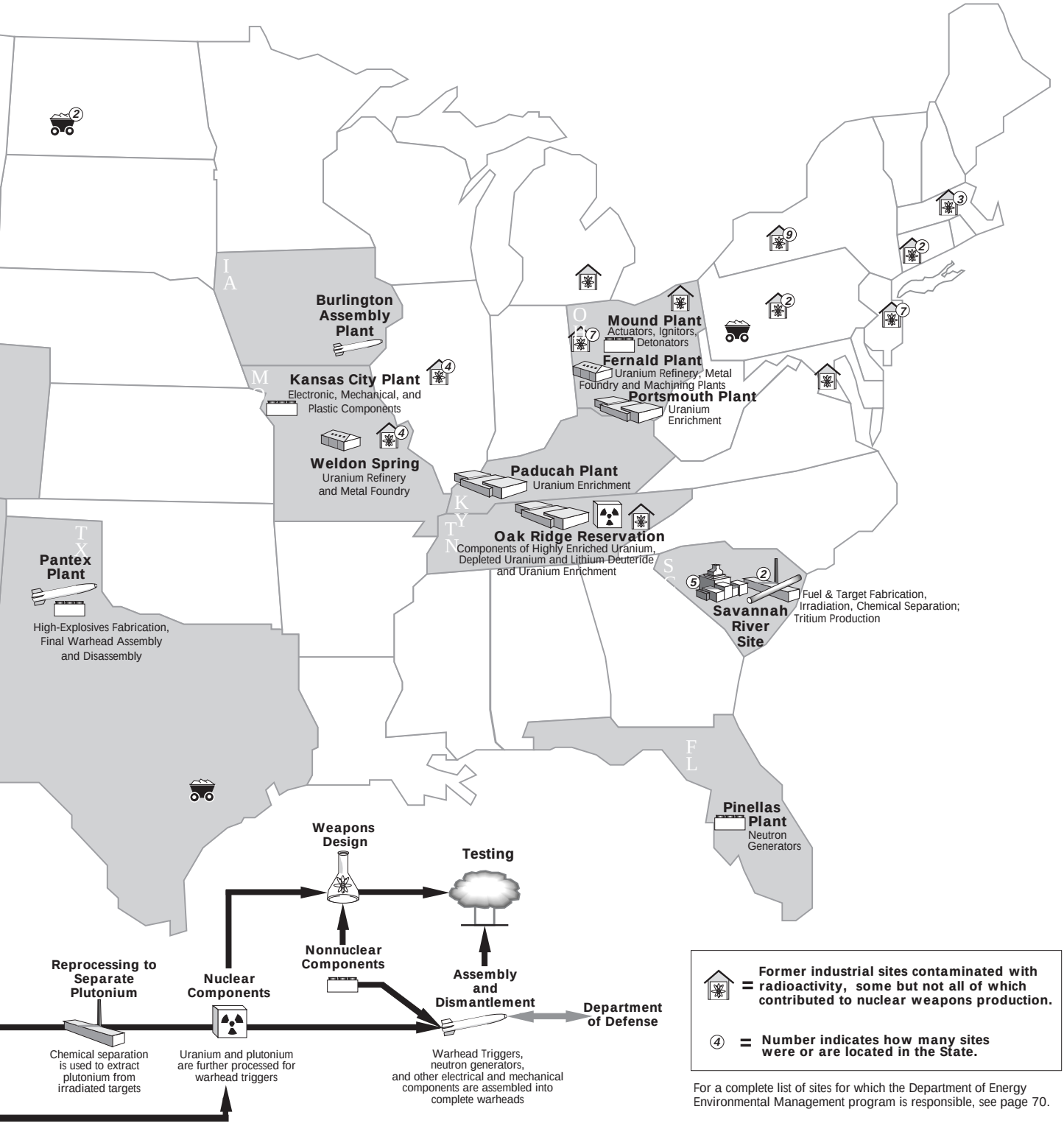
Shortly after World War II, relations between the United States and the Soviet Union began to sour, and the Cold War ensued. Its most enduring legacy was the nuclear arms race. It began during the Manhattan Project, when the Soviet Union began to develop its own atomic bomb.

In the United States, the nuclear arms race resulted in the development of a vast research, production, and testing network that came to be known as "the nuclear weapons complex." Some idea of the scale of this enterprise can be understood from the cost: from the Manhattan Project to the present, the United States spent approximately 300 billion dollars on nuclear weapons research, production, and testing (in 1995 dollars). During half a century of operations, the complex manufactured tens of thousands of nuclear warheads and detonated more than one thousand.

At its peak, this complex consisted of 16 major facilities, including vast reservations of land in the States of Nevada, Idaho, Washington, and South Carolina. In its diversity, it ranged from tracts of isolated desert in Nevada, where weapons were tested, to warehouses in downtown New York that once stored uranium. Its national laboratories in New Mexico and California designed weapons for production in Colorado, Florida, Missouri, Ohio, Tennessee, and Washington. Even now, long after some of the sites used in the nuclear enterprise were turned over to other uses, the Department of Energy–the Federal agency that controls the nuclear weapons complex–owns 2.3 million acres of land and 120 million square feet of buildings.

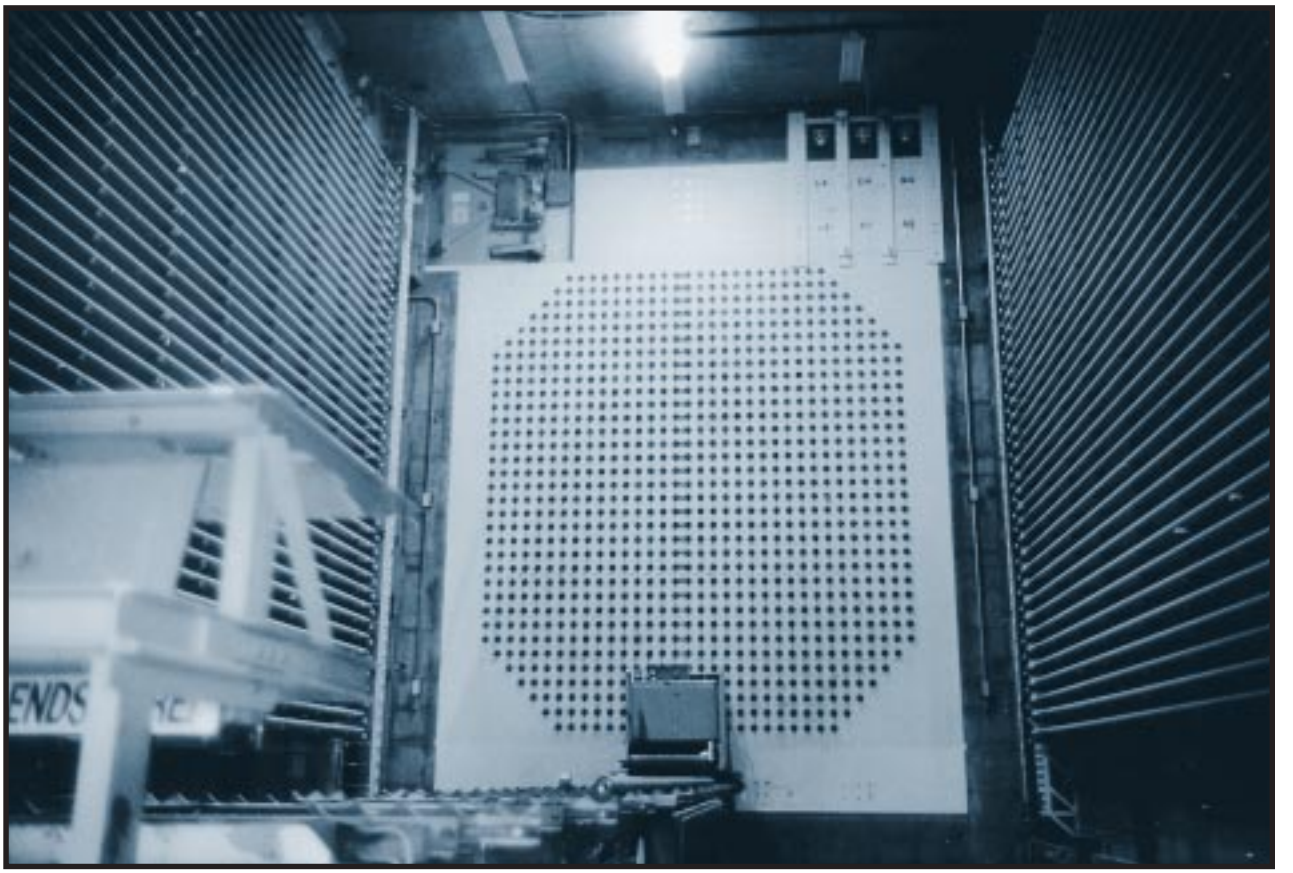


Nuclear Weapons Complex



For a complete list of sites for which the Department of Energy Environmental Management program is responsible, see page 70.

The United States nuclear weapons complex comprised dozens of industrial facilities and laboratories across the country. The weapons production infrastructure originated with the Mahattan Project during World War II and evolved and operated until the late 1980s. It typically employed more than 100,000 contractor personnel at any one time. From the Manhattan Project to the present, the United States has spent approximately $300 billion on nuclear weapons research, production, and testing (in 1995 dollars).



The face of the N Reactor core is made of graphite and measures 39 by 33 by 33 feet. Channels cut horizontally into the graphite held nuclear fuel and uranium "target" slugs. When the slugs were bombarded with neutrons, some of the uranium was transformed into plutonium. During the Cold War the United States operated a total of 14 plutonium-production reactors, creating approximately 100 metric tons of plutonium for its tens of thousands of nuclear warheads. *Hanford Site, Washington. December 16, 1993.*

Civilian Control

Soon after the destructiveness of nuclear weapons was demonstrated by the bombing of Hiroshima and Nagasaki, the U. S. Congress acted to put the immense power and possibilities of atomic energy under civilian control. The Atomic Energy Act of l946 established the Atomic Energy Commission, to administer and regulate the production and uses of atomic power.

The work of the Commission expanded quickly from building a stockpile of nuclear weapons to investigating peaceful uses of atomic energy (such as research on, and the regulation of, the production of electrical power). It also conducted studies on the health and safety hazards of radioactive materials.

In 1975, the Atomic Energy Commission was replaced by two new Federal agencies: the Nuclear Regulatory Commission, which was charged with regulating the civilian uses of atomic energy (mainly commercial nuclear power plants), and the Energy Research and Development Administration, whose duties included the control of the nuclear weapons complex. In 1977, these duties were transferred to the newly created Department of Energy.

Environmental Legacy of the Cold War

Like most industrial and manufacturing operations, the nuclear weapons complex has generated waste, pollution, and contamination. However, many problems posed by its operations are unlike those associated with any other industry. They include unique radiation hazards, unprecedented volumes of contaminated water and soil, and a vast number of contaminated structures ranging from reactors to chemical plants for extracting nuclear materials to evaporation ponds.

Early in the nuclear age, scientists involved with the weapons complex raised serious questions about its waste-management practices. Shortly after the establishment of the Atomic Energy Commission, its 12-man Safety and Industrial Health Advisory Board reported that the "disposal of contaminated waste in present quantities and by present methods...if continued for decades, presents the gravest of problems."

The imperatives of the nuclear arms race, however, demanded that weapons production and testing be given priority over waste management and the control of environmental contamination.

Environmental Management

Although the nation continues to maintain an arsenal of nuclear weapons, as well as some production capability, the United States has entered a new era, and the Department of Energy has embarked on new missions. The most ambitious and far-ranging of these missions is dealing with the environmental legacy of the Cold War. In 1989 the Office of Environmental Management was established for that purpose.

Just as the Energy Department's mission of maintaining the nation's nuclear weapons arsenal consists of a number of different tasks, the new mission of Environmental Management involves a variety of interrelated activities. These activities are often generalized simply as "cleanup." In reality, the mission includes four major activities that involve a great deal more than just "cleanup."

Six Goals of Environmental Management

Maintaining surplus facilities, containing radioactive waste, and cleaning up contamination requires a different strategy from weapons production. Assistant Secretary Thomas P. Grumbly has established six goals for the Department of Energy's environmental management program:

- Eliminate and manage urgent risks in our system.
- Emphasize health and safety for workers and the public.
- Establish a system that is managerially and financially in control.
- Demonstrate tangible results.
- Focus technology development on identifying and overcoming obstacles to progress.
- Establish a stronger partnership between the Department of Energy and its stakeholders.

Barrels of transuranic waste sit on a concrete pad in temporary storage. This waste is contaminated with traces of plutonium, which is dangerous if inhaled and will remain a hazard for hundreds of thousands of years. More than 300,000 barrels of such waste from nuclear weapons production are buried or stored around the country. Cleanup efforts throughout the weapons complex will add to the volume of this waste. *Transuranic Waste Storage Pads, E Area Burial Grounds, Savannah River Site, South Carolina. January 7, 1994.*

Empty drums used for storing waste await treatment and disposal at Oak Ridge. These drums corroded prematurely when a 1987 waste-stabilization project failed to follow guidelines for combining waste sludge with cement. *K-1417 Drum Storage Yards, Pond Waste Management Project, Oak Ridge, Tennessee. January 10, 1994.*

The first major activity is managing *urgent and high-risk nuclear materials and facilites.* For example, the reprocessing plants are no longer needed for the extraction of weapons-grade plutonium, and the nuclear materials inside are not intended to be used for nuclear weapons. The task of stabilizing these facilities and the extraordinarily sensitive material inside them to prevent leaks, explosions, theft, terrorist attack, or avoidable radiation exposures is part of the mission of Environmental Management. Maintaining these facilities has become more difficult because many of them are more than 40 years old. Many have reached or exceeded the lifetime they were designed for and have begun to deteriorate; they must be stabilized merely to protect the safety of cleanup workers. This stable condition must be achieved and the facilities and material must be kept in a safe condition before any decontamination and decommissioning can be undertaken.

Environmental Management also supports international nuclear nonproliferation policies. Specifically, spent-fuel elements removed from reactors were recently returned from other countries to the United States because they contained weapons-grade uranium of U.S. origin. The United States thereby reduced the international trade of weapons-usable highly enriched uranium.

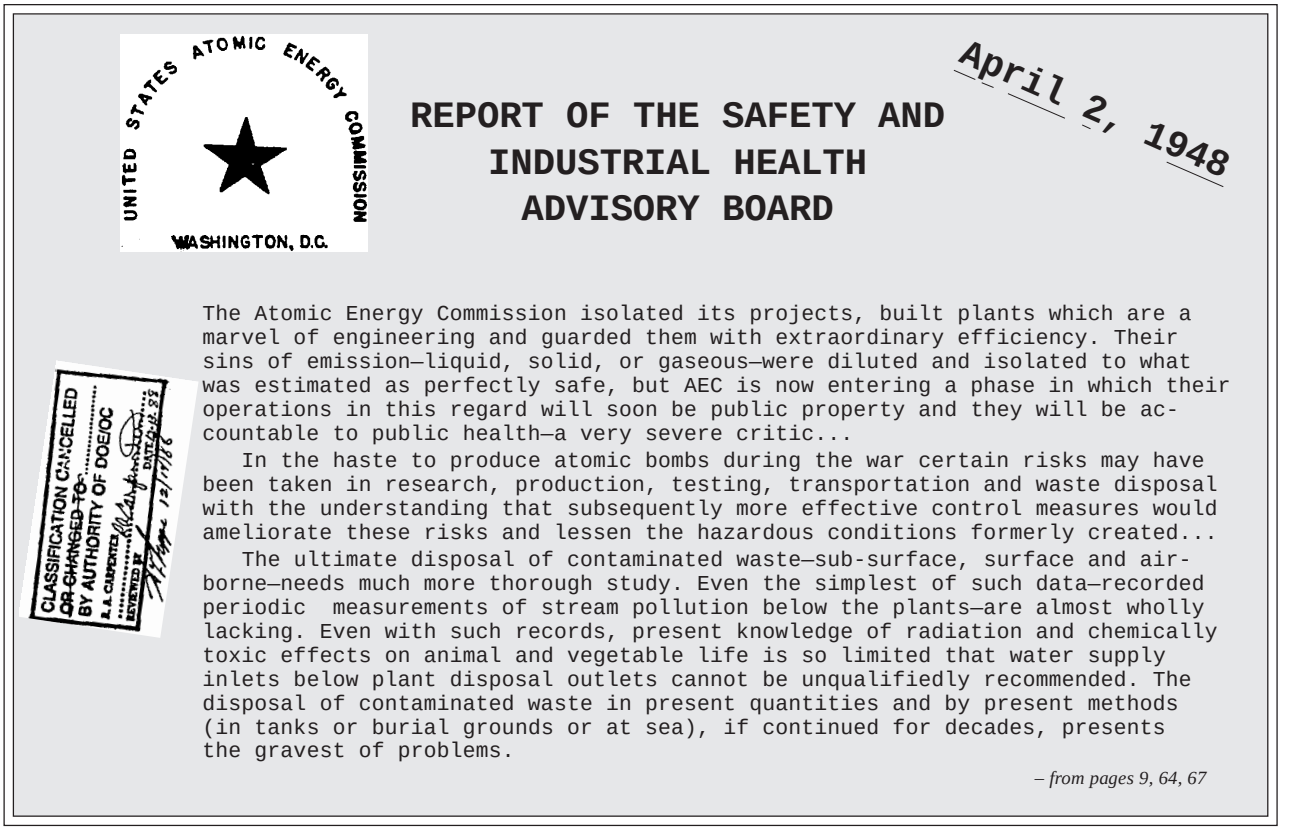
The second major activity is *managing a large amount and variety of wastes*. The primary source of these wastes is the nuclear weapons activities of the Cold War. In addition, the Department also manages some waste from nuclear reactor research and basic science projects, as well as some waste generated by the commercial nuclear power industry under certain circumstances, such as the debris from the accident at the Three Mile Island reactor. Most of the waste generated by the Energy Department is radioactive, and therefore cannot be eliminated – it can only be contained while its radioactivity diminishes. A large volume of waste has already been disposed of at Department of Energy facilities. However, the wastes that remain in storage pending permanent disposal contain most of the radioactivity. These wastes, which will typically remain hazardous for thousands of years, are intended for deep geologic disposal. Part of the task of the Office of Environmental Management is to conduct the scientific investigations required to determine the suitability of a deep salt mine already excavated in New Mexico for plutonium-contaminated waste.

In addition, waste management includes designing, building, and operating a variety of treatment facilities to prepare waste for disposal. Providing safe storage for the enormous quantities of waste is itself a monumental challenge. At the Hanford Site, for example, the Department maintains a constant vigil over huge underground tanks of highly radioactive waste, and it has recently installed a pump in one tank that was at risk of exploding.

The third major activity, *environmental restoration*, is the activity that is usually visualized when the program is described simply as "cleanup." This part of the program encompasses a wide range of activities, including stabilizing contaminated soil; pumping, treating, and containing ground water; decontaminating, decommissioning, and demolishing process buildings, nuclear reactors, and chemical separation plants; and exhuming sludge and buried drums of waste. The challenges are both technical and institutional. In many cases, no safe or effective technology is yet available to address – or even fully understand – the contamination problem. Choosing the right course of action requires the involvement of

Environmental Management includes four major activities that involve much more than just "cleanup."

"Pit Nine" is a radioactive-waste burial ground. From 1967 to 1969, approximately 150,000 cubic feet of plutonium-contaminated and low-level radioactive waste was buried here. Recordkeeping that does not meet today's standards, and failed waste containment have made Pit Nine a daunting remediation challenge for engineers, who must now sample these wastes, exhume them, and treat them thermally. *Radioactive Waste Management Complex, Idaho National Engineering Laboratory. March 16, 1994.*



UNITED STATES ATOMIC ENERGY COMMISSION
WASHINGTON, D.C.

April 2, 1948

REPORT OF THE SAFETY AND INDUSTRIAL HEALTH ADVISORY BOARD

CLASSIFICATION CANCELLED OR CHANGED TO ... BY AUTHORITY OF DOE/OC

The Atomic Energy Commission isolated its projects, built plants which are a marvel of engineering and guarded them with extraordinary efficiency. Their sins of emission—liquid, solid, or gaseous—were diluted and isolated to what was estimated as perfectly safe, but AEC is now entering a phase in which their operations in this regard will soon be public property and they will be accountable to public health—a very severe critic...

In the haste to produce atomic bombs during the war certain risks may have been taken in research, production, testing, transportation and waste disposal with the understanding that subsequently more effective control measures would ameliorate these risks and lessen the hazardous conditions formerly created...

The ultimate disposal of contaminated waste—sub-surface, surface and airborne—needs much more thorough study. Even the simplest of such data—recorded periodic measurements of stream pollution below the plants—are almost wholly lacking. Even with such records, present knowledge of radiation and chemically toxic effects on animal and vegetable life is so limited that water supply inlets below plant disposal outlets cannot be unqualifiedly recommended. The disposal of contaminated waste in present quantities and by present methods (in tanks or burial grounds or at sea), if continued for decades, presents the gravest of problems.

– from pages 9, 64, 67

environmental regulatory agencies, State and local governments, and the general public. Where possible, contaminated buildings and equipment are restored to prepare them for other uses. The main objectives are to avoid additional problems, minimize hazards to workers and the public, and minimize the cost and risks passed on to future generations.

The fourth major activity, *technology development,* is perhaps the most vital to the long-term success of the environmental management mission. The Energy Department is conducting a variety of applied research to develop more effective and less expensive remedies to the environmental and safety problems of the nuclear weapons complex. Some of this research has already yielded signficant results. A good example is a technique, known as Minimum Additive Waste Stabilization, that was demonstrated at the Fernald site in Ohio to convert low-level radioactive waste into flattened glass pebbles, which are easy to handle and will remain stable after disposal. The success of this research is demonstrated not only by improvements in environmental protection but also by the commercialization of these technologies.

Solving the problems of the Cold War's environmental legacy will take many decades, enormous financial resources, and continued guarding and monitoring of sites.

A temporary tension-support structure is being constructed at Fernald. These lightweight structures are increasingly used throughout the former nuclear weapons complex. They keep drums of various types of waste out of the elements, extending their storage life at relatively low cost. *Plant 1 pad, Fernald Environmental Management Project, Fernald, Ohio. December 28, 1993.*

Closing the Circle

The Cold War is over, but its legacy remains. Solving the waste-management and contamination problems of this legacy will take many decades and hundreds of billions of dollars. Even then the task will not be fully completed. Many sites and facilities will need continued guarding and monitoring.

In speaking about the evolution of life on earth, scientist Barry Commoner said:

The first photosynthetic organisms transformed the ...linear course of life into the...first great ecological cycle. By closing the circle, they achieved what no living organism alone can accomplish–survival. Once the links between the separate parts of the problem are perceived, it becomes possible to see new means of solving the whole.

The task of Environmental Management is to begin to close the circle on the splitting of the atom for weapons production through sustained efforts to understand the whole problem as well as its parts.

The Challenges Before Us

The nation faces daunting institutional and technical challenges in dealing with the environmental legacy of the Cold War. We have large amounts of radioactive materials that will be hazardous for thousands of years; we lack effective technologies and solutions for resolving many of these environmental and safety problems; we do not fully understand the potential health effects of prolonged exposure to materials that are both radioactive and chemically toxic; and we must clear major institutional hurdles in the transition from nuclear weapons production to environmental cleanup.

These problems cannot be solved by science alone. In the midst of the complexities and uncertainties, one thing is clear: the challenges before us will require a similar–if not greater–level of commitment, intelligence, and ingenuity than was required by the Manhattan Project.